Supplementary Material

1. Luminance and Intensity. Total power in Watts received by a sensing aperture of area A may vary with time as

$$\Phi(t) = \int \phi(\lambda, t) d\lambda \tag{1}$$

where ϕ is the power spectral density as a function of wavelength λ measured over very short times and may be seen to vary due to random or deterministic processes over longer times t. The total luminous flux, in units of lumens, a spectrally filtered and normalized power, is defined as

$$\Phi_v(t) = \int_{\lambda_1 = 380\ nm}^{\lambda_2 = 750\ nm} \phi(\lambda, t). v(\lambda) d\lambda \tag{2}$$

where $v(\lambda)$ is a spectral weighting, or luminous efficacy for photopic vision, also known as the photopic sensitivity function, in units of lumens/W.

Total incident intensity unfiltered by the receiver is (in units of W/m^2),

$$I(t) = \frac{d\Phi(t)}{dA} \tag{3}$$

Surface luminance is then spectrally filtered and normalized intensity received via

$$\mathcal{L}_p(t) = \frac{d\Phi_v(t)}{dA} . \alpha^{-1} \tag{4}$$

where α, the solid angle resolution of the receiver for a given pixel, is a time-independent constant.

Luminance has the same time dependence and statistical fluctuations scaled only by a constant time-invariant factor as spectrally filtered intensity.

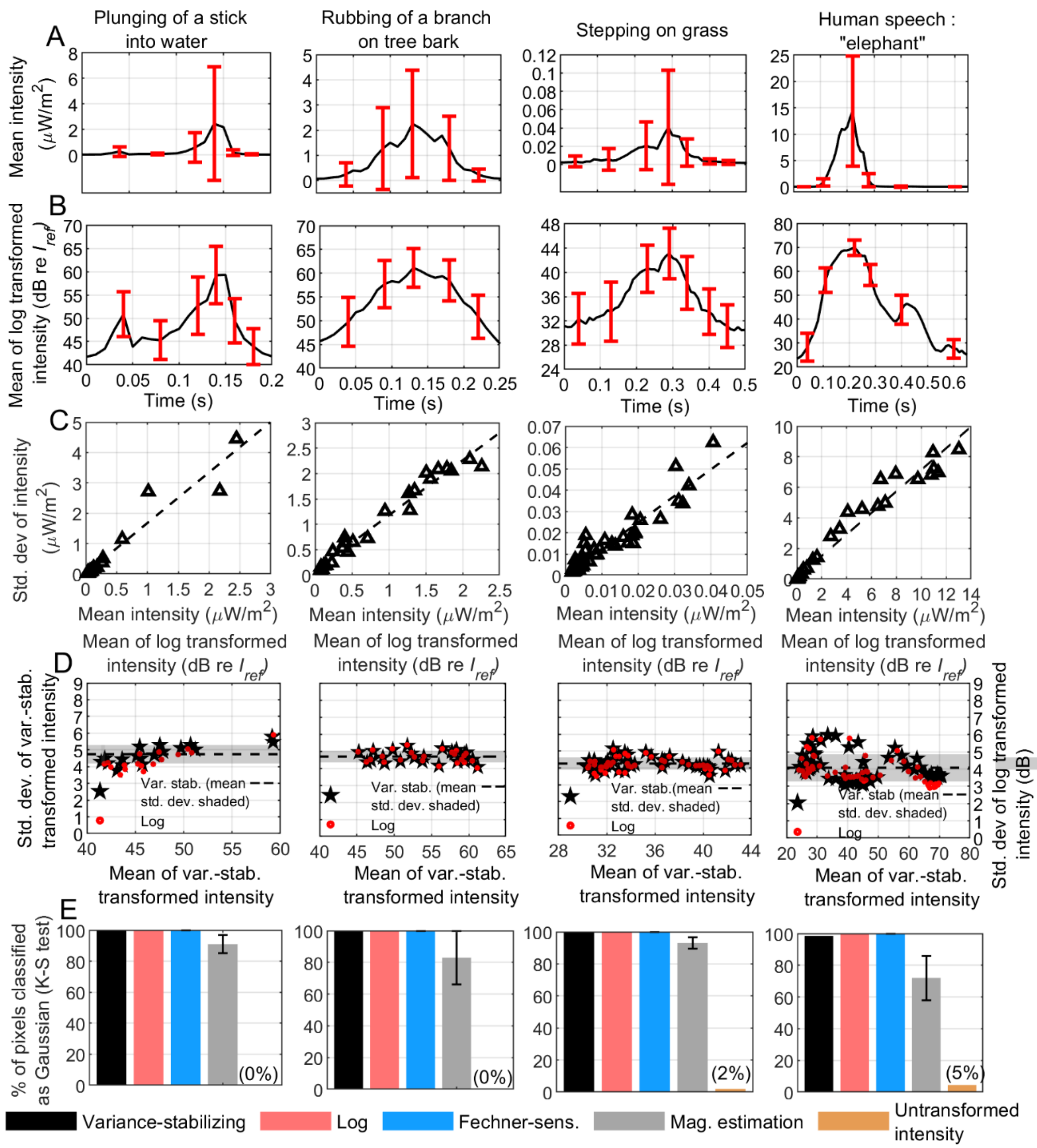

Figure S1. Same as figure 1d-g and figure 5a, for other natural sound signatures, showing consistency of results. Data is in the 128 Hz critical band about 1 kHz. Number of samples for the different acoustic signatures (in columns, left to right) are 70, 190, 82 and 138 respectively. Log transformed intensity in (B) is expressed in dB re I_{ref} which is equivalent to sound pressure level in dB re 20 μPa, where $I_{ref} = P_{ref}^2/(\rho_a c_a)$, $P_{ref} = 20\ \mu Pa$, $\rho_a = 1\ kg/m^3$ density of air, and $c_a = 340\ m/s$ sound speed of air. Standard deviation of variance-stabilizing transformed intensity across pixels in (D) has mean value shown in dashed (--) and standard deviation shown as shaded gray area.

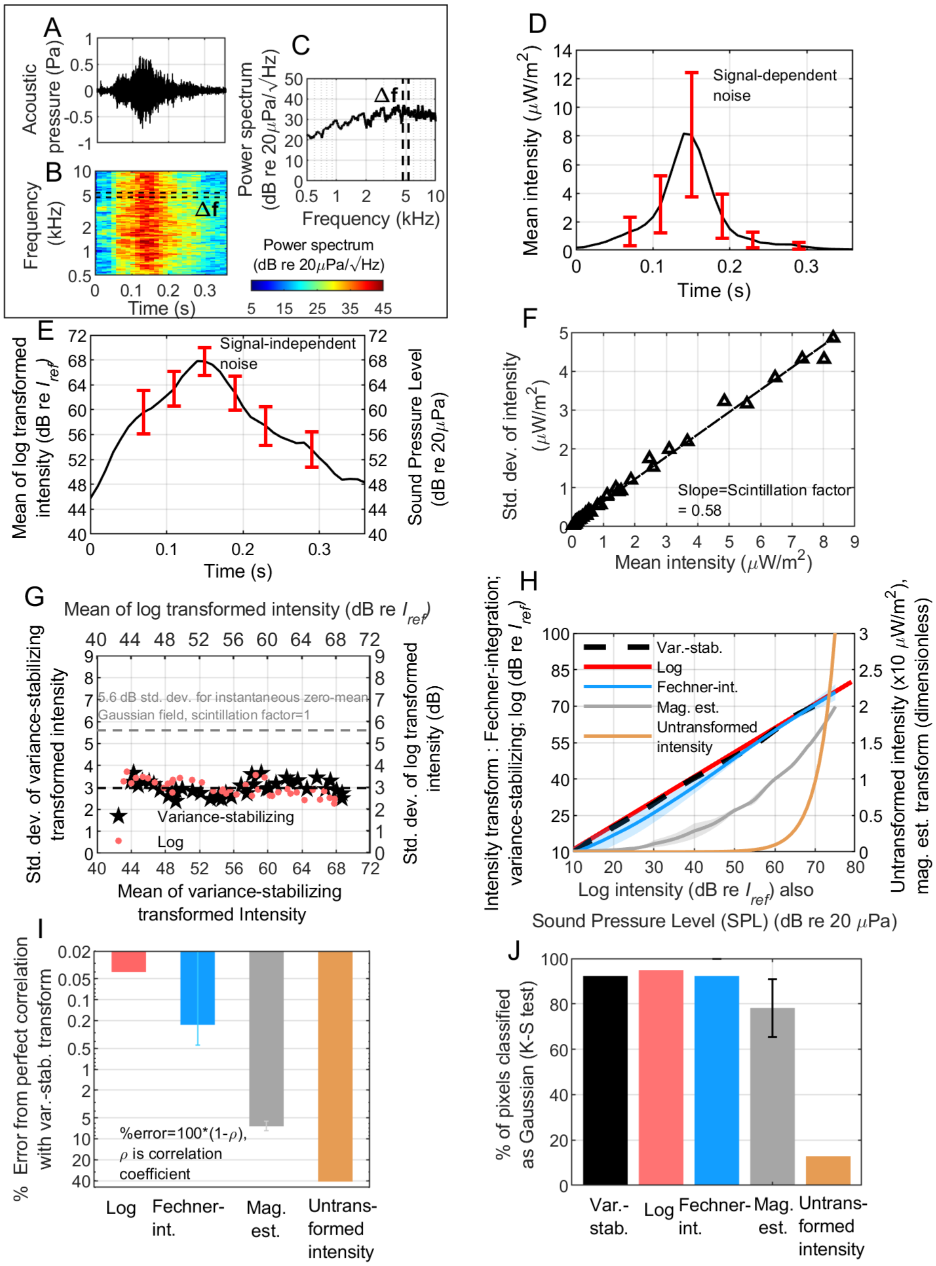

Figure S2. Same as figure 1 but with data and analysis over the human auditory critical band of 330 Hz centered at 5 kHz, which is just beyond the most sensitive range of human hearing [56]. Number of samples, $N = 150$. Fechnerian and magnitude estimation transforms in (H-I) are derived from data in the subset of psychophysical investigations of figure 1h-i that fill the entire 330 Hz critical band centered at 5 kHz, specifically references [5, 6, 7, 9, 49, 51].

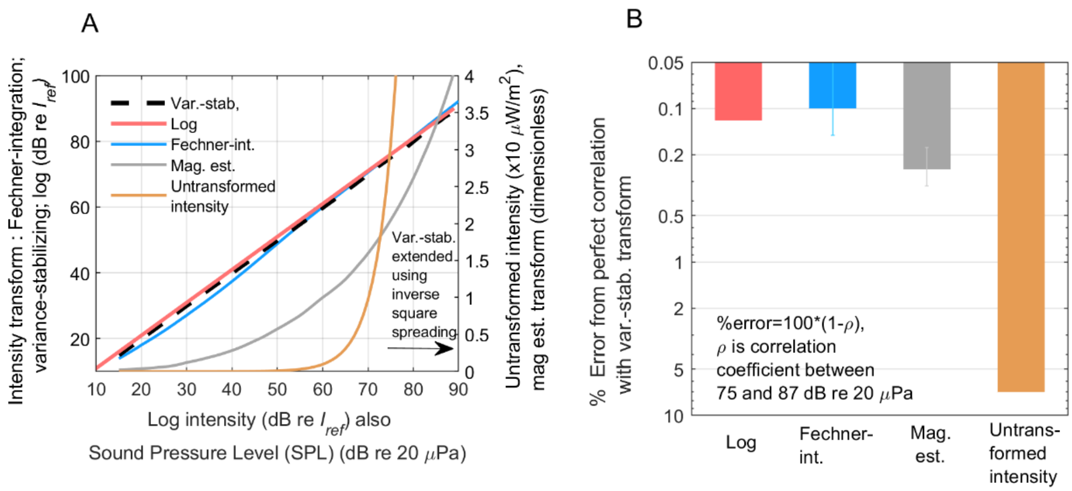

Figure S3. A) Same as figure 1h but with variance-stabilizing transform extrapolated from 75 to 87 dB theoretically by use of inverse-square spreading from original source ranges to corresponding intensities at shorter ranges [75]. Fechnerian transforms and magnitude estimation transforms are shown between 15 and 87 dB from the same psychophysical experiments as in figure 1h. B) Same as figure 1i but exclusively for data in the 75-87 dB range where the extrapolation of figure S5A is performed.

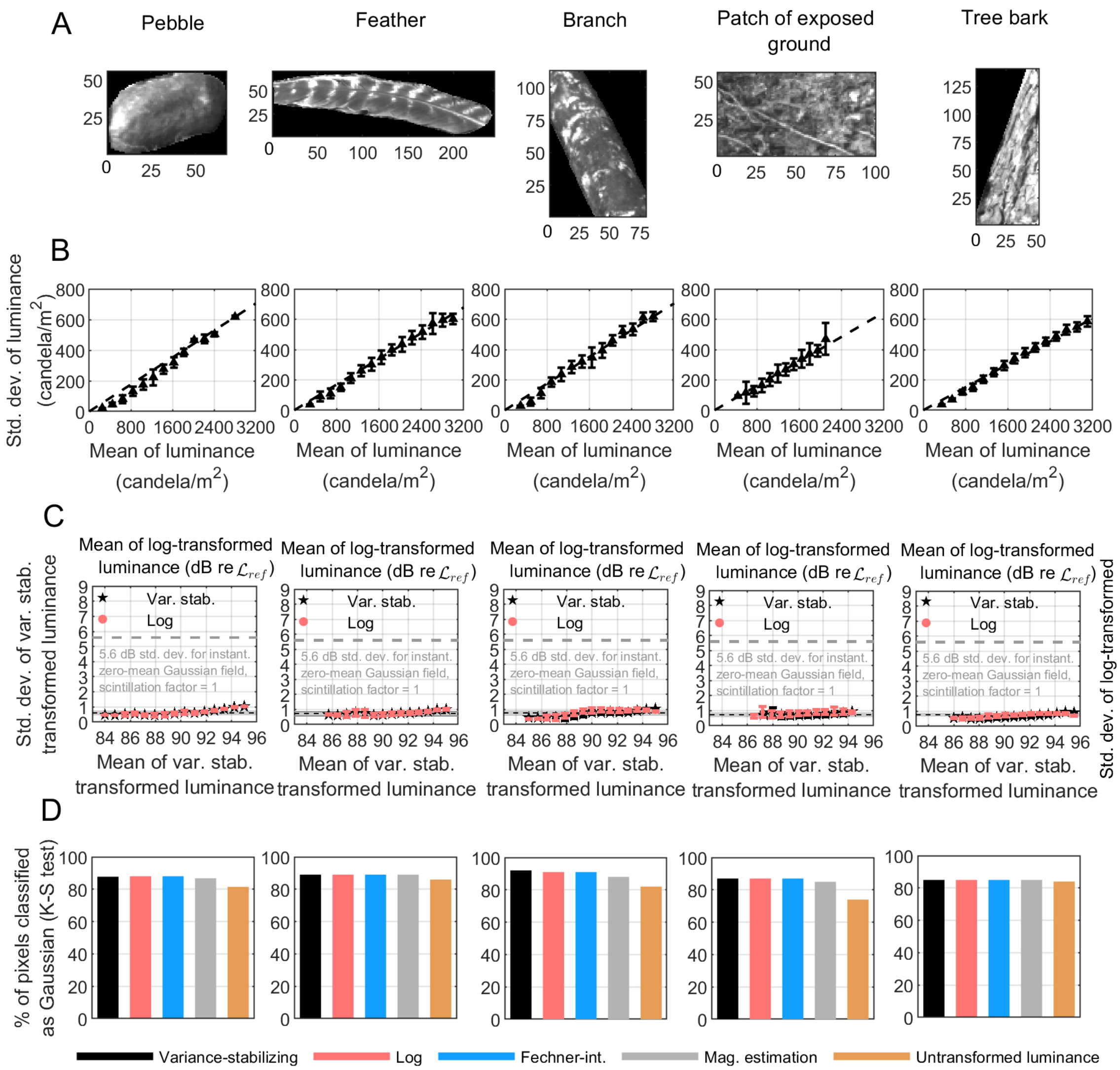

Figure S4. Same as figure 3a-c and figure 5b, reproduced for individual objects within the scene shown in figure 3a. Note, $\mathcal{L}_{ref} = 1\ \mu$candela/m^2.

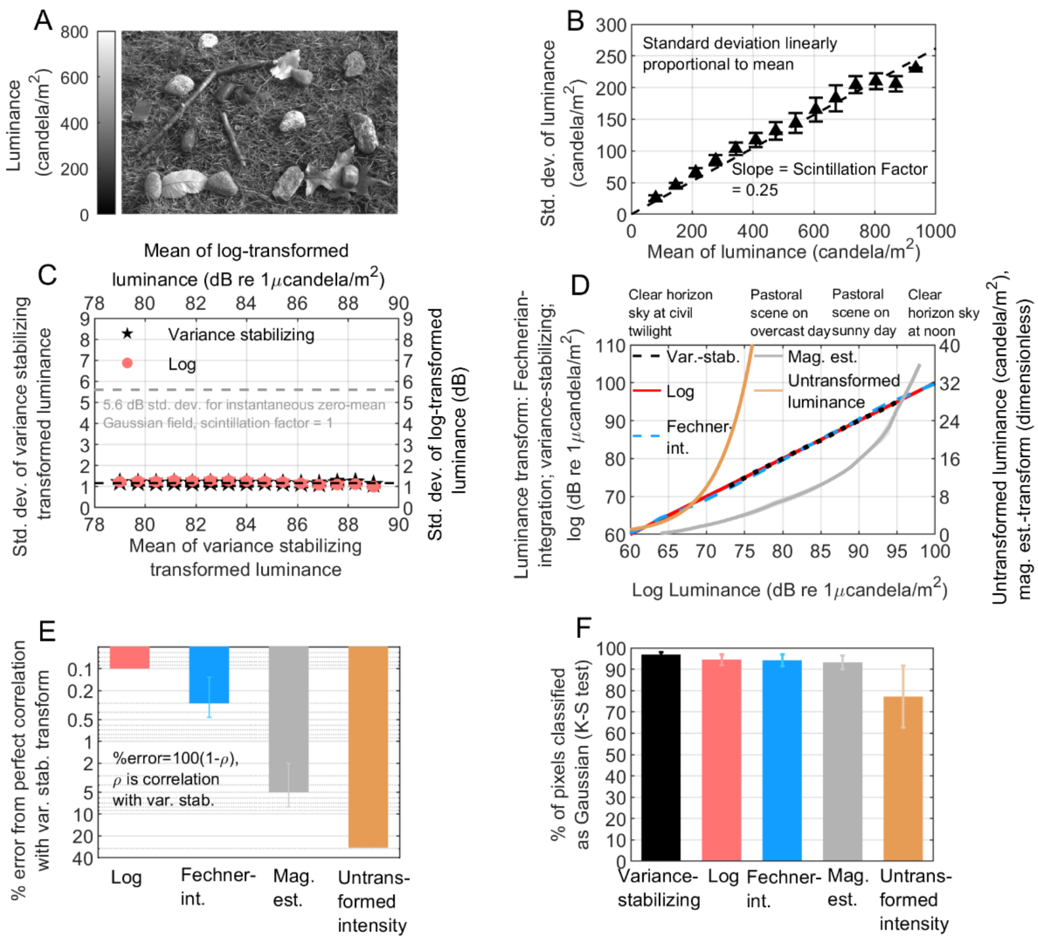

Figure S5. Same as figure 3 but for a scene on sunny day with <25% cloud cover. Entire scene sampled every second over roughly 1 hour in the afternoon. Standard deviation of log-transformed luminance across pixels is 0.252 dB after instantaneous image offset of equation 5.1. The e-folding time scale of the autocorrelation is found to be roughly 150 s.

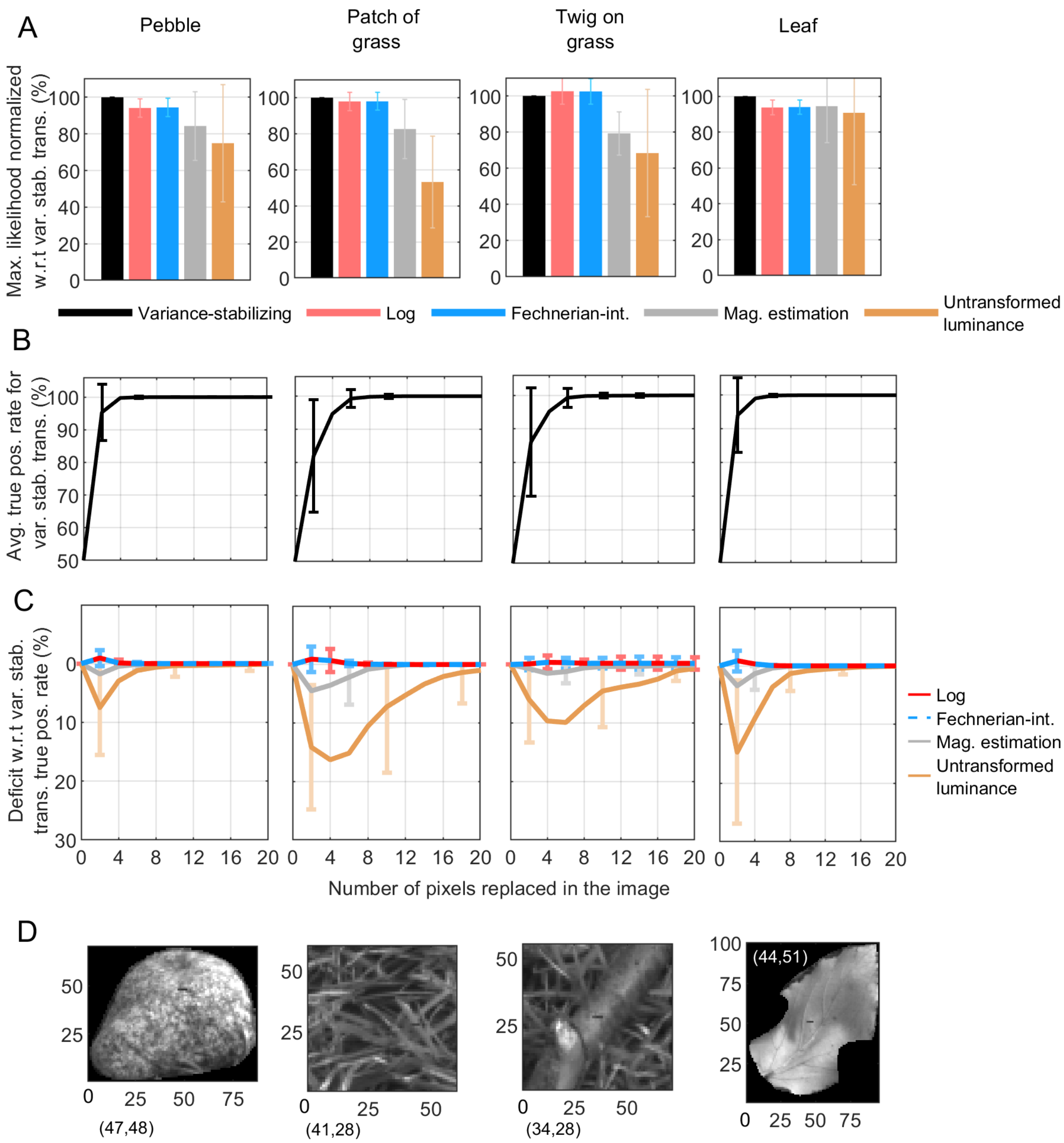

Figure S6. Same as figure 8 for objects on sunny day with <25% cloud cover.

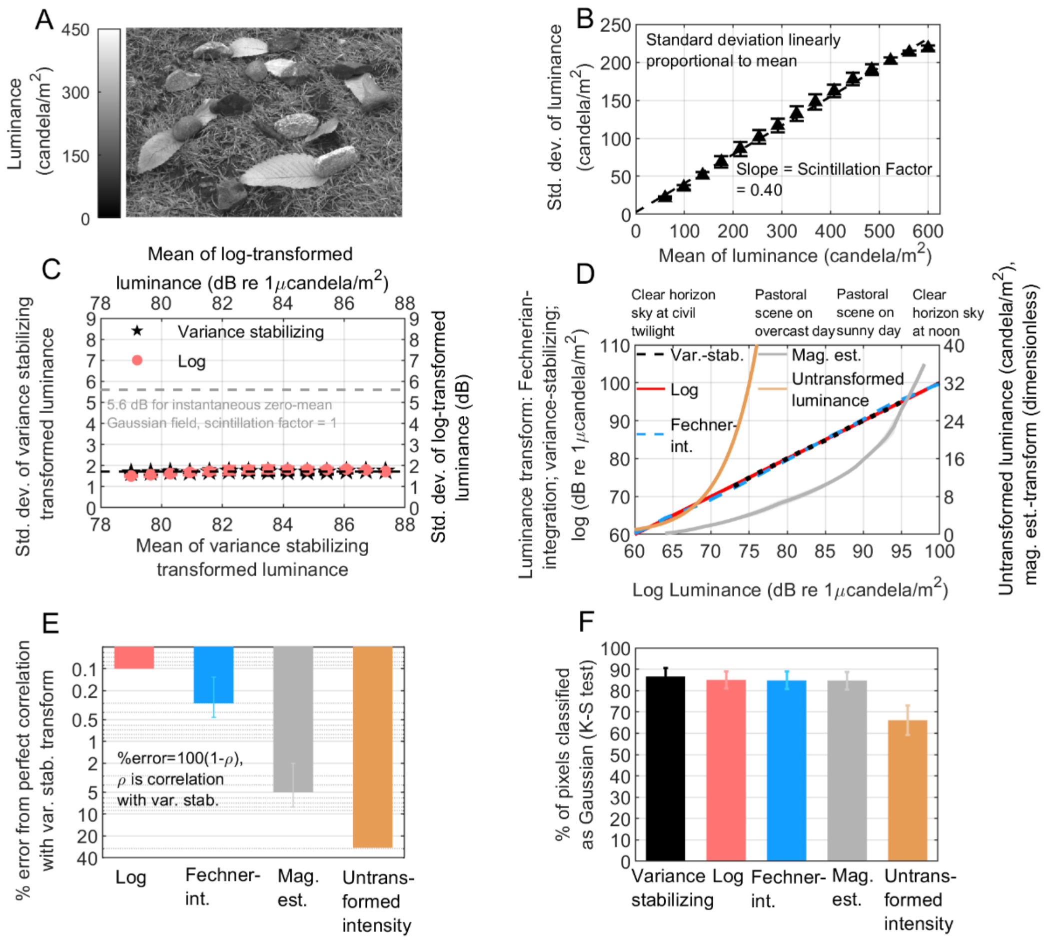

Figure S7. Same as figure 3 but for a scene on overcast day with >70% cloud cover. Entire scene sampled every second over roughly 3.5 hours at midday. Standard deviation of log-transformed luminance across pixels is 0.391 dB after instantaneous image offset of equation 5.1. The e-folding time scale of the autocorrelation is found to be roughly 121 s.

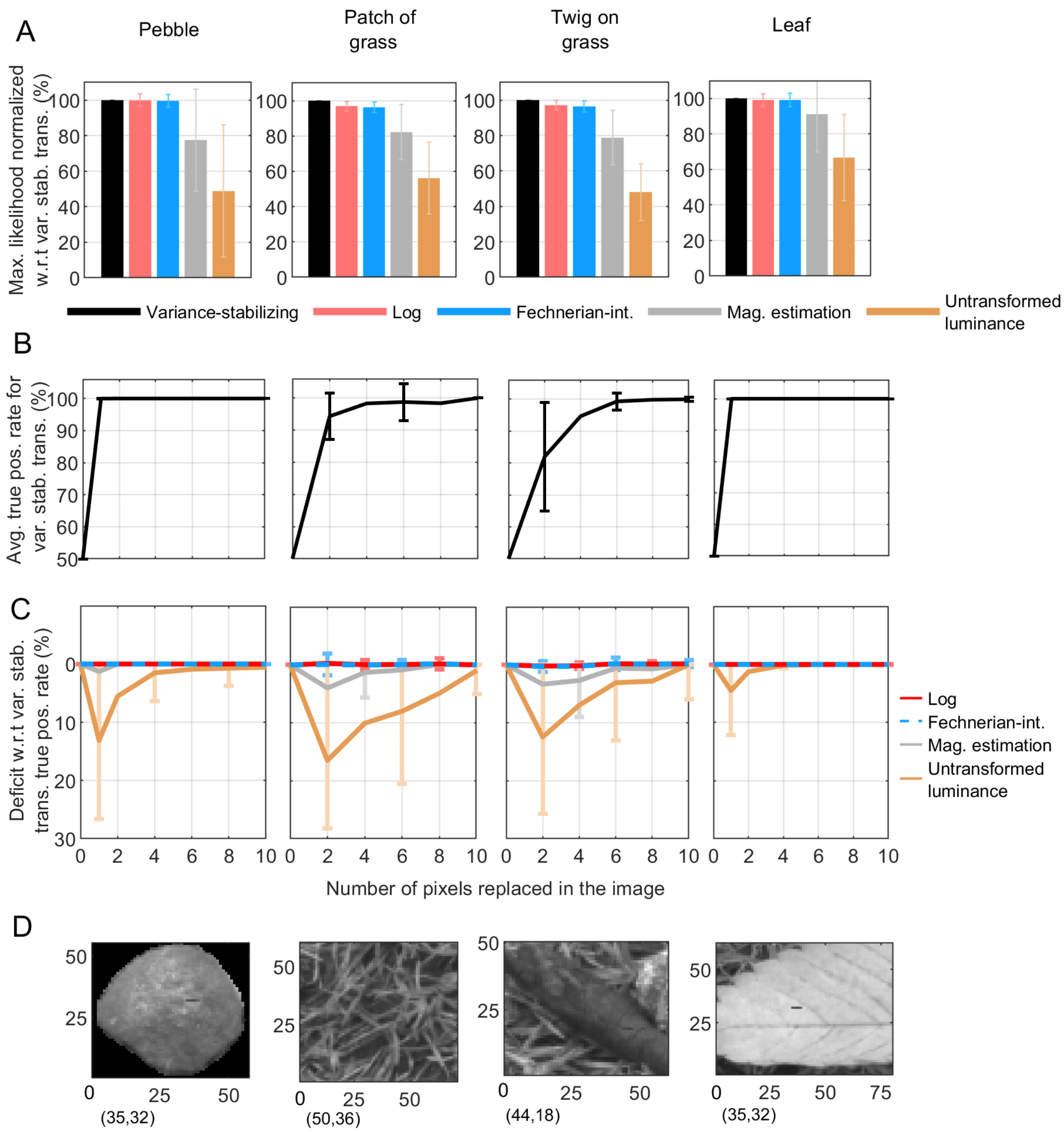

Figure S8. Same as figure 8 for objects on overcast day with >70% cloud cover.

Experiment	Linear scaling factor
Miller 1947	0.0935
Viemeister 1974	0.2249
Moore and Raab 1975 experiment 1	0.2141
Moore and Raab 1975 experiment 2	0.1739
Raab and Goldberg 1975 experiment 1	0.1850
Raab and Goldberg 1975 experiment 2	0.2862
Houtsma et al. 1980	0.1782
Fastl and Zwicker 2006	0.1155

Table S1. Multiply normalized just-noticeable differences in figure 2a for each experiment by the corresponding linear scaling factors to obtain original just-noticeable-differences of that experiment. Each independent experiment employed acoustic signal stimuli of differing duration and different human subjects which lead to best-fit lines with differing slopes across experiments. Miller 1947: signal duration = 1.5 s; Viemeister 1974: signal duration = 0.2 s; Moore and Raab 1975 experiment 1: signal duration = 0.25 s; Moore and Raab 1975 experiment 2 (different subject from experiment 1): signal duration = 0.25 s; Raab and Goldberg 1975 experiment 1: signal duration = 0.1 s; Raab and Goldberg 1975 experiment 2 (different subject from experiment 1): signal duration = 0.1 s; Houtsma et al. 1980: signal duration = 0.5 s; Fastl and Zwicker 2006: signal duration = 0.2 s.

Experiment	Linear scaling factor
Koenig-Brodhun 1888	0.0325
Hecht 1934	0.0260
Craik 1938	0.0187
Blackwell 1946 (Experiment 1)	0.0774
Blackwell 1946 (Experiment 2)	0.0183
Blackwell 1946 (Experiment 3)	0.0128
Blackwell 1946 (Experiment 4)	0.0091
Blackwell 1946 (Experiment 5)	0.0075
Cornsweet 1965 (Experiment 1)	0.1468
Cornsweet 1965 (Experiment 2)	0.1673
Davson 1980	0.0467
Gloriani 2016 (Experiment 1)	0.0485
Gloriani 2016 (Experiment 2)	0.0259

Table S2. Multiply normalized just-noticeable differences in figure 4a for each experiment by the corresponding linear scaling factors to obtain original just-noticeable-differences of that experiment. Each independent experiment employed differing stimulating-luminance-patch angular width and different human subjects which lead to best-fit lines with differing slopes across experiments. Angle subtended by stimulating luminance patch from subject's eye is ϕ. Koenig-Brodhun 1888: $\phi > 120$ arc-minutes; Hecht 1934: $\phi = 56$ arc-minutes; Craik 1938: $\phi > 120$ arc-minutes; Blackwell 1946 (Experiment 1): $\phi = 3.6$ arc-minutes; Blackwell 1946 (Experiment 2): $\phi = 9.68$ arc-minutes; Blackwell 1946 (Experiment 3): $\phi = 18.2$ arc-minutes; Blackwell 1946 (Experiment 4): $\phi = 55.2$ arc-minutes; Blackwell 1946 (Experiment 5): $\phi > 120$ arc-minutes; Cornsweet 1965 Experiment 1: ϕ not provided; Cornsweet 1965 Experiment 2 (different pre-stimulus condition from Experiment 1): ϕ not provided; Davson 1980: ϕ not provided; Gloriani 2016 (Experiment 1): $\phi = 27$ arc-minutes; Gloriani 2016 (Experiment 2): $\phi = 120$ arc-minutes. Blackwell 1946 used five varying stimulus-patch sizes to experimentally investigate the dependence of just-noticeable-difference on patch subtended angle.

References:

The citations 1-74 refer to the References in the main article and Methods section. The citation 75 to References included here.

[75] Beranek, Leo (1954). *Acoustics*. New York: McGraw-Hill.